

# The role of ultrasound imaging in disease diagnosis and monitoring the effects of physiotherapeutic treatment of the lumbosacral spine – an overview of research

## Rola obrazowania ultrasonograficznego w diagnozowaniu schorzeń oraz monitorowaniu efektów terapii fizjoterapeutycznych kręgosłupa lędźwiowo-krzyżowego – przegląd badań

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### Key words

oblique and transverse abdominal muscles – ultrasound imaging (USG) – lumbosacral spine – motor organ diseases

### Abstract

Ultrasound Imaging (USG) is a method being increasingly used in physiotherapy. It is applied successfully in the study of joints, tendons and muscles. Muscle ultrasound examination is helpful in diagnosing and the choice of medicinal and therapeutic methods for the treatment of motion organ diseases and monitoring the effects of the utilised physiotherapeutic methods. Therefore, it is used by doctors and increasingly, by physiotherapists. The aim of the study is to present the role of abdominal muscle ultrasound imaging in the diagnosis of lumbar-spine disorders on the basis of the latest available research findings. Literary research was carried out on the basis of a systematic review of domestic and foreign studies in the analysed area. The first part of the paper contains theoretical aspects of the USG examination, including the basics of its use and the principles of exercise, illustrating the potential for using ultrasound imaging as a method of examining the oblique and transverse abdominal muscles. The second part of the article is, in turn, an aggregated set of available results of research on the effectiveness, credibility and reliability of this method in the diagnosis of lumbar spine diseases as well as in monitoring the effects of physiotherapy. The second part of the article ends with the development of a catalogue of drawbacks and advantages of ultrasound imaging in the treatment of motion organ illnesses. The final part of the study is an analysis of the future aspect, with particular emphasis on the direction of development of ultrasound imaging in both orthopaedics, rheumatology and physiotherapy.

### Słowa kluczowe

mięśnie skośne i poprzeczne brzucha – obrazowanie ultrasonograficzne (USG) – odcinek lędźwiowo-krzyżowy kręgosłupa – schorzenia narządu ruchu

### Streszczenie

Obrazowanie ultrasonograficzne (USG) narządu ruchu jest metodą coraz częściej wykorzystywaną w fizjoterapii. Stosowane jest z powodzeniem w badaniu zarówno stawów, ścięgien jak i mięśni. Badanie USG mięśni jest pomocne w diagnozowaniu oraz doborze leczniczych i terapeutycznych terapii schorzeń narządu ruchu oraz pozwala monitorować efekty zastosowanych metod fizjoterapeutycznych. W związku z tym, jest wykorzystywane przez lekarzy, a także coraz częściej przez fizjoterapeutów. Celem opracowania jest ukazanie roli obrazowania USG mięśni brzucha w diagnozowaniu schorzeń odcinka lędźwiowo-krzyżowego kręgosłupa na podstawie najnowszych, dostępnych w literaturze wyników badań. Badanie literaturowe zrealizowane zostało na podstawie przeglądu badań krajowych i zagranicznych z analizowanego zakresu. Pierwsza część artykułu zawiera teoretyczne aspekty badania USG narządu ruchu, w tym podstawy jego zastosowania i zasady wykonywania oraz przedstawia

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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możliwości zastosowania obrazowania USG jako metody badania mięśni skośnych i poprzecznych brzucha. Drugą część artykułu stanowi z kolei zagregowany zbiór dostępnych wyników badań z zakresu skuteczności, wiarygodności oraz niezawodności tej metody w diagnozowaniu schorzeń odcinka lędźwiowo-krzyżowego kręgosłupa jak również w monitorowaniu efektów terapii fizjoterapeutycznych. Zwieńczenie drugiej części artykułu stanowi opracowanie katalogu wad i zalet metody obrazowania ultrasonograficznego w leczeniu schorzeń narządu ruchu. Finalną częścią opracowania jest z kolei analiza aspektu przyszłościowego ze szczególnym uwzględnieniem kierunków rozwoju obrazowania USG narządu ruchu zarówno w ortopedii, reumatologii jak i fizjoterapii.

## INTRODUCTION

Ultrasound imaging (USG) is a diagnostic method commonly used in medicine and more and more often, in physiotherapy, where it is used in the examination of joints, tendons, ligaments, muscle insertion and muscles<sup>1,2</sup>.

Based on a review of research by Rhodes and Bishop, in which subject-related literature was analysed regarding ultrasound diagnosis of the spine and soft tissues over the past 27 years, the conclusion was that ultrasound imaging technology is very important for clinicians who prefer non-invasive methods for diagnosis of spinal and soft tissue disorders<sup>3</sup>.

Thanks to its properties, ultrasound becomes a helpful tool in the diagnosis of motor organ disorders. In addition, it is a method used to assess paraspinal and spine stabilising muscles at all levels. Therefore, it is often used in cyclical monitoring of results and to assess the effectiveness of implemented physical therapy treatments<sup>4</sup>.

The aim of this study is to show the role of abdominal muscle ultrasound imaging in the treatment of lumbosacral spine diseases based on a systematic review of the results of domestic and foreign research, and also to develop a catalogue of the advantages and disadvantages of this method in the assessment of motor organ disorders.

## TECHNICAL BASES OF MOTOR ORGAN ULTRASOUND IMAGING

Before beginning an ultrasound examination of the musculoskeletal system, an interview should be conducted with the patient re-

garding whether s/he has undergone any treatments or surgeries of the muscular or bone systems. Bone structure tests can also be performed. During the ultrasound examination, the patient's well-being should be ensured in order to reduce the feeling of discomfort within the area under examination. The position of the patient should be convenient, allowing good access to the examined structures. The location where the probe is applied to the test area should be chosen in relation to characteristic topographic points. For the interpretation of the image to be correct, regardless of who performs the test or interprets it, there are several rules organising an image on the monitor:

1. Left part of the image – structures located closer and medially;
2. Right part of the image – structures located further and laterally;
3. Upper part of the image – structures located superficially;
4. Lower part of the image – deeply located structures<sup>5</sup>.

When testing the joints and tissues, different ultrasonic wave frequencies are used. In the case of muscle, tendon, adipose tissue and skin tests, mainly 5 MHz or 7.5 MHz probes are selected. By means of carefully designated probes, it is possible to observe each and every skeletal muscle. Measuring the cross-section of muscles is widely used in monitoring the progress of rehabilitation. When testing muscles, it is not necessary to observe constant monitoring planes. Local changes are examined within the area of the changes. In ultrasound examination of the muscles, it is very important that the ultrasound wave fall on the muscle perpendicularly, not exerting too much pressure on the muscles during examination<sup>5</sup>.

## ULTRASOUND IMAGING AS A METHOD OF EXAMINING THE OBLIQUE AND TRANSVERSE ABDOMINAL MUSCLES

The ultrasound imaging method is very useful in examining and monitoring both the spine and muscles. Using ultrasound imaging, it is also possible to monitor the intervertebral disc. The structure of the disc is extremely important in the treatment of back pain. In order to examine the structure and assess its degree of degeneration, in their study, McNally et al.<sup>6</sup> used a 3.5 MHz probe. The study was carried out among 13 subjects, at the height of the thoracic and lumbar spine. To obtain the best image, a posterior lateral approach approx. 1-2 cm from the middle dorsal line was used. It was possible to observe the intervertebral discs at the height of the Th<sub>11</sub> to the L<sub>3</sub> in at least 54% of subjects<sup>6</sup>.

Particularly visible in ultrasound imaging are the abdominal muscles (transverse muscle, oblique internal, external, rectus abdominis muscle, especially its lumbar part). They are clearly demarcated, which makes it easy to measure them cross-sectionally and to observe real-time contraction and relaxation. It is also possible to analyse all phases of the planned movement.

Dynamic ultrasonographic examination during movement, or sonofeedback (SFB), is a useful method in learning how to properly contract muscles and maintain movement control. Therefore, it is an effective tool in physiotherapy. It enables customisation of more individualised therapy to a patient's needs<sup>7</sup>. Via sonofeedback, it is possible to observe isolated contraction

of the transverse and oblique muscles of the abdomen during lumbar spine stabilisation exercises<sup>8</sup>.

## **EFFICACY, RELIABILITY AND CREDIBILITY OF ULTRASOUND EXAMINATION IN THE TREATMENT OF LUMBOSACRAL SPINE DISEASES - AVAILABLE RESEARCH RESULTS**

Ultrasound imaging is a key method for many Polish and foreign researchers in the study of abdominal muscles. It is often used in the development of individualised therapies for the treatment of lumbosacral spine diseases. However, in addition to monitoring the effects of therapy, this method is also often essential in diagnosing patients complaining of persistent pain in the lumbosacral spinal region.

Due to the above, ultrasound is subject to many topic-related studies. Several dozens of them were analysed by Koppenhaver et al.<sup>9</sup> in a trial designed to provide an answer to the question whether ultrasound imaging is a measure of the size of trunk muscles and activation of them during isometric contractions. 37 subject-related studies were taken into consideration. The conclusion was drawn that the use of ultrasound in rehabilitation is justified due to the precision of muscle size measurements at rest and during isometric contraction. It was also found that they show sensitivity to any tissue changes, both those positive and negative.

The vast majority of other available studies confirm the great number of advantages of ultrasound as a diagnostic imaging method. Analysing individual reports, it can be noted that the results of many of them, obtained independently of the examined groups, particularly confirm the reliability, credibility and effectiveness of using ultrasound in physiotherapy. And thus:

1. The reliability has been confirmed:  
a) In the research by Chung and Young<sup>10</sup>, conducted in Hwaseang, South Korea in 2015. It

has been proven that this method can be successfully used as a reliable tool for measuring abdominal muscle thickness in asymptomatic patients at rest and during muscle contraction. The study included 30 patients (20 men and 10 women). The group was selected on the basis of exclusion criteria. The test was carried out using a 7.5 MHz linear probe. In order for the measurement to be objective and reproducible, the position of the probe was determined relative to the topographic points of the body. In this case, the probe was placed on the right upper iliac crest along the mid axillary line. The position for examining the abdominal transverse muscles at rest in each case was the same – supine position; while in order to capture the muscle in contraction, the subjects were instructed to lift the lower limbs 20 cm above the body's line. The measurement was carried out 3 times. The first and the second one were an hour apart, and the third was taken after one week. The thickness of the transverse muscle was measured between the hyperrechogetic fascia lines. The obtained measurements were expressed as arithmetic mean and standard deviation. To assess the reliability of the measurement, correlation coefficient and standard measurement error were calculated. Statistical analysis was performed at the confidence level of 95%. The reliability coefficient is defined within the following intervals:

I < 0.4 – poor reproducibility;  
II 0.4-0.75 – good reproducibility;  
III > 0.75 – excellent reproducibility.

On the basis of the above-mentioned scale of the reliability coefficient, the following results were obtained: abdominal transverse muscle thickness at rest characterised by reliability at 0.65-0.77 (good reproducibility, interval II), while in contraction at 0.85-0.86 (excellent reproducibility, interval III)<sup>10</sup>.

b) In the Sung Doo Park<sup>11</sup> study conducted in 2013, USG was considered a reliable method for measuring the thickness of the transverse and oblique muscles of the abdominal and internal muscles in patients with lumbosacral spinal pain at rest and during muscle activity. The study was conducted among 20 patients with diagnosed lumbar spine pain syndromes. According to the VAS scale, the perceived level of pain among the examined patients ranged from 5 to 7 points. Muscle testing at rest was performed in supine position, while muscle spasms were caused by consciously tensing the abdomen by the patients on command. The measurement was performed 3 times with 10-second intervals. The test used a 7.5 MHz linear probe. The probe was positioned above the iliac crest at the height of the axillary line half way between the lowest rib and the tip of the hip bone. The average from 3 trials was used in the analysis, which was carried out based on the intraclass correlation coefficient (ICC). For the external oblique muscle at rest, the ICC ratio was 0.55. However, for the oblique external muscle, ICC = 0.97 (high reliability). Standard error was from 0.14 to 0.50. However, the results of measurements of the same muscles in contraction were as follows: abdominal transverse muscle ICC = 0.82, external oblique - ICC = 0.95. Standard error ranged between 0.28 and 0.61<sup>11</sup>.

c) In the study by Koppenhaver et al.<sup>12</sup> conducted in Salt Lake City, Utah, USA in 2009, abdominal muscle measurement reliability was also confirmed at rest during ultrasound in patients with pain symptoms. Patients with lumbar spine pain syndromes participated in the study. The testing was carried out at 2 stages with an interval of 1 to 3 days. The percentage change in muscle thickness was calculated. The intraclass correlation coefficient (ICC)

was used to estimate the reliability of measurements. The study was conducted by 2 researchers. Taking the average from 2 measurements, reliability assessment (ICC) ranged from 0.96 to 0.99 for tests performed on the same day, while comparison on the third day ranged from 0.87 to 0.98. The ICC estimates comparing the tests performed by the 2 researchers of the same image ranged from 0.96 to 0.98<sup>12</sup>.

d) In the research by Henderson et al.<sup>13</sup>, published in 2015, scientific studies on ultrasound diagnostics in musculoskeletal pathologies were analysed. Literature analysis was based on studies having been published in the previous 40 years (including up until mid-2014). The literature has been analysed in 2 separate categories:

- 1) Diagnostics of musculoskeletal system ultrasound imaging, focusing on morphological features and structural inseparability of the neuromuscular and skeletal systems, rehabilitation ultrasound imaging, which takes the functions of muscles and soft tissues related to them during exercise and physical activity into account.
  - 2) Analyses have shown that diagnostic ultrasound imaging of the joints, soft tissues, spine and limbs in both categories 1) and 2) is characterised by good accuracy and diagnostic reliability<sup>13</sup>.
2. The reliability of the ultrasound method has been confirmed by, among others:
- a) The Hoopes et al.<sup>14</sup> study, conducted in 2015 at several clinical centres in the USA, in which the reliability of the ultrasound method examining all abdominal muscles has been proven. The study involved 33 professionally active, healthy soldiers without any spinal pain complaints. The measurement was carried out in 3 positions: lying, standing and standing with a load. The changes in the thickness of transverse and abdominal oblique muscles

in percentages and the intraclass correlation coefficient (ICC) were calculated. The measurement was performed 3 times in each position, during contraction and relaxation of the abdominal muscles. The value of the ICC reliability coefficient ranged from 0.90 to 0.98.

- b) In the study by Chen et al.<sup>15</sup> carried out in 2014, it was confirmed that muscular corset ultrasound examination, both on the posterior and anterior sides, is reliable in the comprehensive assessment of muscle condition. The study involved 20 volunteers without spinal pain symptoms. The test was performed in a lying position. Abdominal muscle thickness was measured at rest and during contraction. Pearson's correlation coefficient was used to analyse the results. The correlation coefficient in this study ranged from 0.89 to 0.98.

3. The effectiveness of the method has been confirmed, among others, by:

- a) Heidari et al.<sup>16</sup> (Boston, USA and Tehran, Iran). The study was conducted from the end of 2013 to 2014. Based on scientific reports on the use of ultrasound imaging in abdominal muscle examinations, it was established that using this test to measure muscle thickness is an effective method diagnosing the causes of lumbosacral spine pain. On the basis of analysis regarding scientific literature from available medical databases, the effectiveness of imaging in diagnosing and treating lower back pain can be confirmed.

- b) In the Czyrny<sup>17</sup> study from 2012, it was confirmed that high resolution ultrasound is currently the best method used to visualise anatomy and diagnose muscle damage, assuming that the researcher knows the structure of the muscle being examined and knows where s/he should look for damage. In addition, it has been proven that ultrasound can easily show muscle and tendon tissue. Due to the fact that mus-

cle tissue reflects the ultrasound beam to a small degree, the muscle fibres on the ultrasound image are hypoechoic. The tendon tissue, in turn, creates layers that well reflect the ultrasound beams which appear as hyperechogenic lines intertwined with thinner bands of muscle fibres. In addition, the author noticed differences between the ultrasound images of well-trained muscles (wider zones of dark muscle cell bands) and poorly trained or atrophic (light tendon bands dominated in the muscle image).

c) In the study by Chi-Fishman et al.<sup>18</sup> conducted in 2004, it was confirmed that the USG method identifies differences in cross-sections between normal and weakened muscles. In addition, ultrasound can be useful for measuring muscle changes resulting from implemented therapies. The study involved 9 patients subjected to tests in order to determine the condition of their muscles. The ultrasound provided information about the correlation between loose or tense muscles and muscular strength. It also showed differences in diameters of healthy and affected muscles. This is very valuable information when measuring muscle reaction to medications or therapeutic exercises.

- d) In the research by Polish authors Kochański et al.<sup>19</sup> from 2015, it was confirmed that ultrasound enables non-invasive qualitative and quantitative assessment of the transverse abdominal muscle in real time. Thanks to ultrasound, it is also possible to measure the thickness and length of this muscle at rest and during contraction, to check the smoothness of contraction and its control.

## ADVANTAGES AND DISADVANTAGES OF MOTOR ORGAN ULTRASOUND IMAGING

Taking the results of the research on the validity of using ultrasound imaging in the treatment of spinal dis-

Table 1

Advantages and disadvantages of motor organ ultrasound imaging	
ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"><li>• Easily available</li><li>• Non-invasive</li><li>• No requirements regarding special preparation for the test</li><li>• Method convenient both for patients and therapists</li><li>• Quick application</li><li>• Can be used in healthy individuals, those with pain symptoms and asymptomatic</li><li>• Possibility to evaluate structures (muscles, fascia and the borders of bone epiphysis) in real time</li><li>• Facilitation of more detailed diagnosis</li><li>• Relevance of decisions regarding choice of therapy</li><li>• Procedural reliability and muscle thickness measurement precision</li><li>• Allows assessment of muscle loss, atrophy and hypertrophy</li><li>• Confirmation of effectiveness regarding applied methods of physical therapy</li><li>• Possibility to perform testing both during rest and movement (in order to monitor muscle work along its whole length and to assess its efficiency)</li><li>• High measurement compatibility regardless of operator</li><li>• Possibility for sonofeedback</li><li>• Possibility to observe isolated muscle contractions</li><li>• Reliability in muscular corset testing</li><li>• Effectiveness in diagnosing the causes of LS spine pain</li></ul>	<ul style="list-style-type: none"><li>• Training and experience of the therapist performing testing is required</li><li>• Test must be performed using specialist apparatus with a probe dedicated to motor organ ultrasound testing</li></ul>

eases into account, a catalogue of the advantages and disadvantages of this imaging diagnostics method in assessing the condition of patients struggling with motor organ dysfunctions can be created (Table 1).

**DIRECTIONS OF DEVELOPMENT IN ULTRASOUND IMAGING OF THE MOTOR ORGAN IN ORTHOPAEDICS, RHEUMATOLOGY AND PHYSIOTHERAPY – THE FUTURE ASPECT**

Ultrasound is a dynamically developing field of imaging diagnostics. Over the past two decades, ultrasound imaging has become the basic method for examining the abdominal cavity. It is also widely used in gynaecology or cardiology. Initially, the use of ultrasound for monitoring the motor organ encountered many technological barriers resulting from non-adjustment of parameters in ultrasound machines to assess superficial tissues. Through technological advances, the apparatus has been improved providing high frequency probes, which allow to monitor

muscles, tendons, fascia and joints by obtaining a very high resolution image. Therefore, it has become an increasingly used method in orthopaedics, rheumatology and physiotherapy. Ultrasound imaging is still being improved. Thanks to the increasingly modern probes and advanced software processing digital data, the resulting ultrasound image is 3-dimensional and in this way, the imaging effect is similar to CT and MRI. The 3-dimensional USG method will be of particular importance in research on motor organ disorders. Thanks to the spatial image, it will be possible to more accurately assess the dimensions of the structure under examination and precisely determine its location. Another innovative method of ultrasound imaging is using high frequency ultrasounds, by constructing appropriate probes. This test can be used mainly for examining of joints, the integumentary system and subcutaneous tissue<sup>5</sup>.

**CONCLUSIONS**

Ultrasound imaging is a helpful method in diagnosing conditions

and monitoring the effects of physiotherapy in diseases of the motor organ. As confirmed by research reports subjected to analysis, it is a tool that is particularly effective in assessing muscle condition, and thus, in diagnosing various spinal pathologies.

Thanks to a number of advantages of the ultrasound method, the causes of lumbosacral spine diseases can be diagnosed with great success by imaging the oblique and transverse abdominal muscles, which are stabilisers for this segment, and abnormalities in their functioning are a direct predisposition to the occurrence of such disorders as: lumbar discopathy, instability of the spine or its stenosis.

In addition, according to domestic and foreign studies, ultrasound imaging can be considered an effective, reliable and credible method in the treatment of spinal diseases. It is also a future-oriented and developmental method, which, thanks to the possibility of obtaining a better image due to modern technologies, will have even wider application in orthopaedics, rheumatology and physical therapy.

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